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Short communication

Earthworm populations in septic system filter fields and potential effects on wastewater renovation

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ABSTRACT

Wastewater renovation in septic-system filter fields can be affected by preferential flow through soil macropores. Anecic earthworm species make deep vertical burrows that may reduce renovation by acting as preferential flow paths that decrease effluent contact with the soil matrix. On the other hand, endogeic earthworms make largely horizontal burrows that may enhance wastewater renovation by distributing the effluent over a larger area. Additionally, the moist, nutrient-rich environment in filter fields may increase earthworm populations by enhancing their survival. Therefore, our objectives were to determine earthworm numbers and biomass with distance from soil treatment trenches, and identify species present to estimate potential effects on wastewater renovation. Five septic systems were investigated. At each site, earthworm populations were measured using formalin extraction at 10 locations along each of three 7-m long transects perpendicular to the trenches. There were an average of 6.4 times more earthworms and 5.4 times more earthworm biomass within 1 m of the trench than in the background (3.5–7.0 m from the trenches) in 13 of the 15 transects. This suggests that earthworms may have a significant effect on the movement of effluent. Because only epigeic and endogeic species were observed, the potential for reduced renovation and groundwater contamination at these sites is likely low. This may not be the case in areas with large numbers of anecic earthworms.

1. Introduction

In the United States, 21% of homes use onsite wastewater treatment systems (US Census Bureau, 2004). The majority of these systems are soil-treatment systems, which utilize soil to remove pollutants from wastewater (US EPA, 2002). After the wastewater is pre-treated in a septic tank, the effluent is transmitted to gravel-filled trenches where it infiltrates into the soil. The area occupied by the trenches is usually referred to as the filter field. Natural processes, including biologically mediated oxidation, chemical sorption, and physical filtration, remove pollutants as the effluent percolates through the soil (Miller and Wolf, 1976). To ensure adequate renovation, the effluent must contact a great enough volume of soil for a

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sufficient period of time. Therefore, successful renovation is dependent on the soil having an appropriate hydraulic conductivity.

In filter fields, the hydraulic conductivity of the infiltrative surface at the trench–soil interface is particularly important. Bacteria in this region grow under conditions of excess carbonaceous nutrients and store excess polysaccharides as slime capsules (Tyler et al., 1977). The slimy bacterial film coating soil aggregates traps additional bacteria and particles, creating a ''clogging zone'' of reduced hydraulic conductivity (Otis, 1985; US EPA, 2002, p. 4-4). Ideally, the reduced infiltration through this zone will allow unsaturated flow of effluent through the soil below the trench, thus providing a greater volume of aerobic soil for renovation processes.

Preferential flow of effluent in macropores may contribute to incomplete renovation, particularly when macropores intersect the infiltrative surface. Mote and Buchanan (1994) demonstrated that when soil on the bottom of a treatment trench was tilled, renovation improved compared to an undisturbed trench bottom. Tilling disrupted channels formed by roots and earthworms that might have otherwise intersected the base of the trench.

Earthworm-created macropores may have a significant impact on soil renovation of wastewater, particularly if earthworm populations are larger in the moist, nutrient-rich environment near soil-treatment trenches. Infiltration rates at the soil surface can be 4–10 times greater in soils with earthworms than in soils without earthworms (Edwards and Bohlen, 1996). The effect of earthworms on water movement, however, may depend on the species present.

Earthworm species can be classified into three ecological groups, epigeic, endogeic, and anecic, based on their burrowing and feeding habits. Epigeic species burrowing activity is restricted to the upper few centimeters of soil. They feed on decomposing litter on the soil surface and little or no soil is ingested. Endogeic species make largely horizontal burrows and consume mineral soil, preferably rich in soil organic matter. They are usually found in the upper 10–15 cm of soil, but could burrow deeper around trenches due to the enrichment of soil organic matter. Anecic species form vertical burrows, sometimes branched, that extend to the soil surface and can be as deep as 240 cm (Edwards and Bohlen, 1996). They emerge at the surface to feed on decomposing litter, usually pulling the material into their burrows, and they also ingest some soil. Some species' behavior varies from these classifications depending on site-specific environmental conditions (Edwards and Bohlen, 1996). For example, earthworms sometimes burrow deeper to escape cold conditions in the winter and dry conditions in the summer (Edwards, 2004).

Anecic earthworm species are of greatest concern in filter fields because their vertical burrows can act as preferential flow paths that may allow effluent to be transmitted to groundwater before renovation is complete. Shipitalo and Gibbs (2000) demonstrated that anecic earthworm species' burrows near agricultural subsurface drains can transmit injected animal wastes into the drains, negatively impacting water quality where the drain empties into surface bodies of water. Epigeic earthworm species are not expected to influence renovation because their burrowing activity is limited to the upper few cm of soil. Endogeic earthworm species, however, could enhance soil renovation of wastewater by distributing the effluent over a greater area, thereby increasing the volume of soil available to treat the effluent.

Earthworm populations vary greatly depending on many factors, including soil texture, moisture, pH, temperature, and organic matter content (Curry, 2004). In particular, animal wastes can dramatically increase earthworm populations and burrow numbers (Haraldsen et al., 1994). Thus, filter fields may provide a particularly favorable environment for earthworms because of moist soil conditions and an abundance of organic substrate and microorganisms on which earthworms feed.

Little is known about earthworms in relation to soil-treatment-system filter fields. This information is critical to our understanding of earthworm ecology and the processes that effect renovation of household wastewater. Therefore, our objectives were to determine relative earthworm populations and biomass with distance from septic-system trenches and identify species present to estimate potential effects on soil renovation of household wastewaters. We hypothesized that earthworm populations are greater near soil-treatment-system trenches than in the surrounding soil unaffected by effluent addition.

2. Materials and methods

2.1. Site description

Earthworm populations were measured at five soil-treatment systems (A–E) along three transects per site perpendicular to the filter-field trenches. All five systems served single-family households and were 3–25 years old at the time measurements

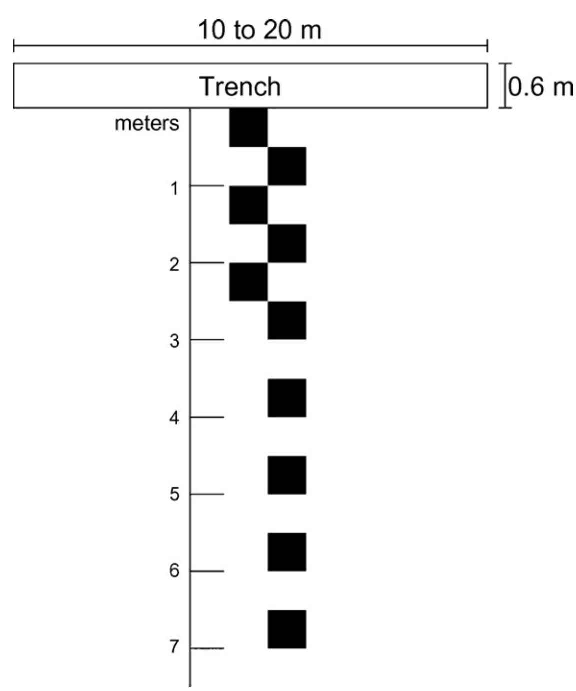

Fig. 1 – Earthworm sampling scheme; the black squares represent earthworm sampling quadrats, which are 0.5 m × 0.5 m.

were made. All sites were in Washington County, Arkansas USA within 8 km of the city of Fayetteville, and the soils were fine-silty, mixed, active, thermic Udults with loamy surface textures (Harper et al., 1969). All sampling was conducted between 19 and 25 November 2005. Fayetteville received about 5 cm of rain during the 2 weeks prior to sampling. No precipitation occurred during the sampling period and average daily temperatures ranged from 4.4 to 14.4 °C.

2.2. *Earthworm sampling procedures*

A relative measure of earthworm numbers and biomass with distance from soil-treatment-system trenches was obtained by sampling earthworm populations at 10 positions along transects 0–7 m from the trenches. Earthworms were extracted by slowly sprinkling 7.6 L of a 0.2% formalin solution (0.08 mol kg^{-1}) on the soil surface inside 0.5 m × 0.5 m quadrats (Baker and Lee, 1993). The first quadrat spanned a distance of 0–0.5 m from the trench, and the next five quadrats were located in a zigzag pattern with increasing distance from the trench along the transect (Fig. 1). This pattern was adopted to minimize cross contamination of the extractant into the other quadrats. The last four quadrats were spaced 0.5 m apart (Fig. 1). Earthworms obtained from individual quadrats were counted, and fresh live weights were obtained for each group. The earthworms were then preserved in a 4% formaldehyde solution. Mature earthworms were later identified based on reference literature (Dindal, 1990; Reynolds, 1977) and verified by Dr. Mac A. Callaham, Research Ecologist, USDA Forest Service Southern Research Station, Athens, Georgia.

3. Results

Distinct trends in earthworm numbers were apparent in 13 of the 15 transects, with transects C2 and C3 as the only exceptions (Fig. 2). In most cases, earthworm numbers were greatest in the first one or two quadrats (0–1 m) from the soil-treatment trenches then declined rapidly with distance. There was little variation in earthworm numbers after ~3 m. Earthworm biomass as a function of distance from the trenches followed trends similar to those observed with earthworm numbers (data not shown). Statistical comparisons using Student's *t*-test (two-sample, assuming unequal variance) revealed that in these 13 transects average earthworm numbers were significantly greater ($P \leq 0.01$) in the two quadrats 0–1 m from the trenches than in the four quadrats 3.5–7 m from the trenches with an average of 6.4 times more

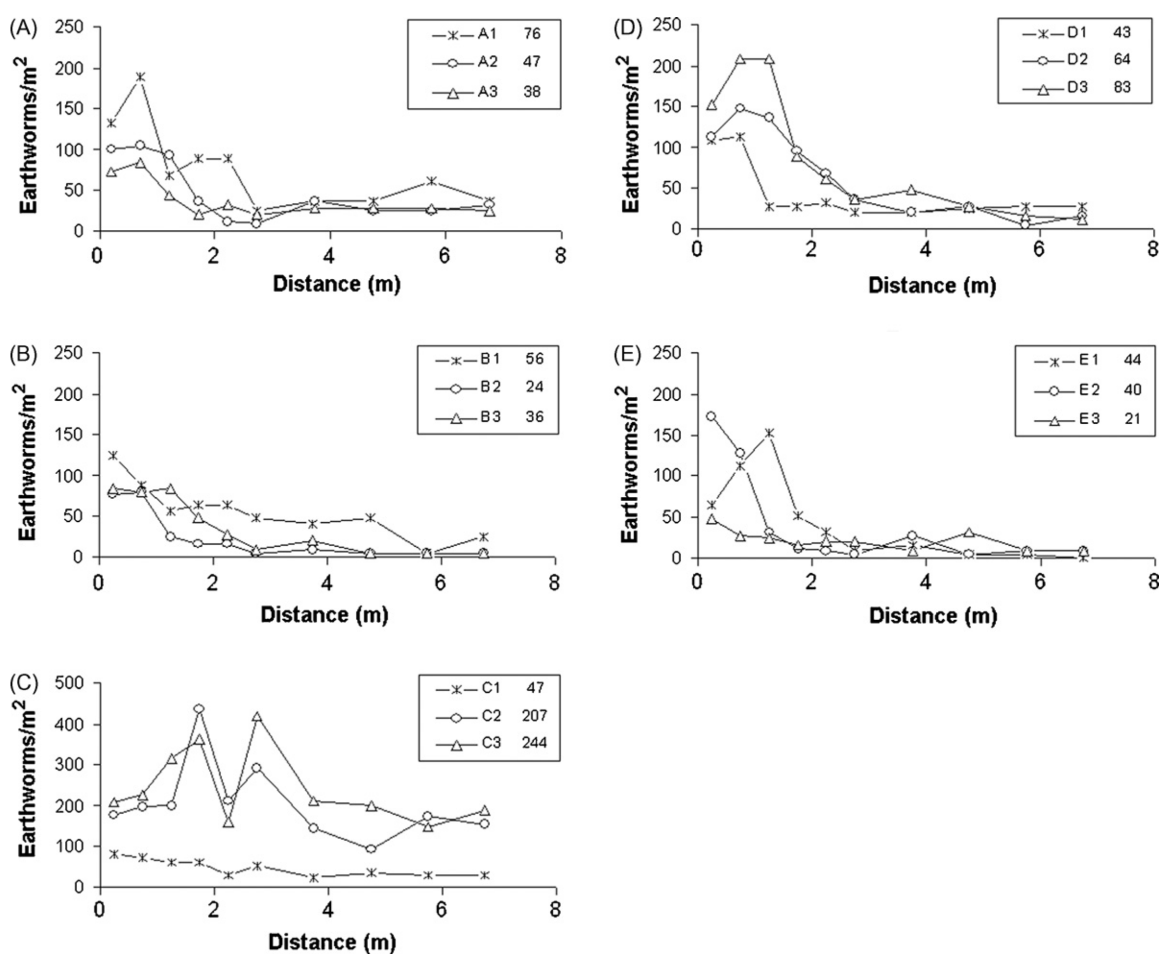

Fig. 2 – Earthworm population with distance from septic system trenches at sites A–E and average earthworms m^{-2} (shown in legends) in each transect. There are three transects per site, and each transect is represented by the site (A–E) followed by the transect number (1–3).

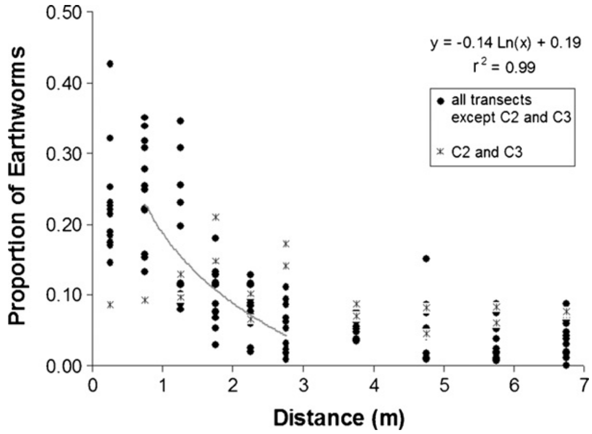

Fig. 3 – Composite of proportion of earthworms out of total number of earthworms sampled for each transect with distance from septic system trenches, and regression analysis for average proportion of earthworms at each distance (all transects except C2 and C3) for sample points between 0.5 and 3 m.

worms (range 2.3–16.3). Likewise, statistical comparison of earthworm biomass revealed that the average biomass was 5.4 times greater (range 1.7–13.7) in the two quadrats nearest the trenches than in those $\geq$3.5 m from the trenches.

To quantify further the trends in populations with distance from the trenches and to compare transects among the five sites, earthworm numbers and biomass in each transect were normalized by converting the data for each quadrat into a proportion of the total collected in each transect. Regression analyses were then performed on the normalized data. Data from transects C2 and C3 were considered outliers and were excluded from these analyses. The regressions indicated that earthworm numbers (Fig. 3) and biomass (Fig. 4) in the 13 remaining transects followed similar trends and declined

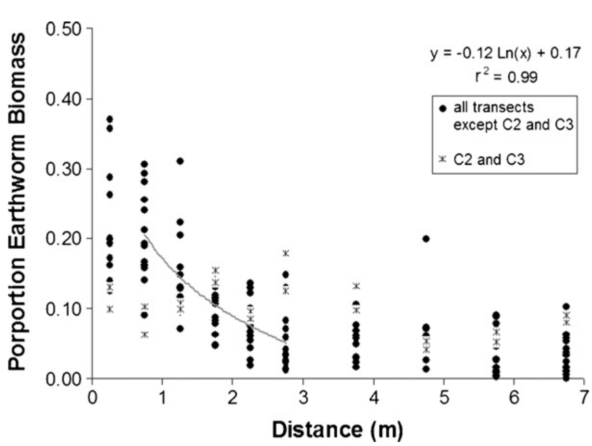

Fig. 4 – Composite of proportion of earthworm biomass out of total earthworm biomass sampled for each transect with distance from septic system trenches, and regression analysis for average proportion of earthworm biomass at each distance (all transects except C2 and C3) for sample points between 0.5 and 3 m.

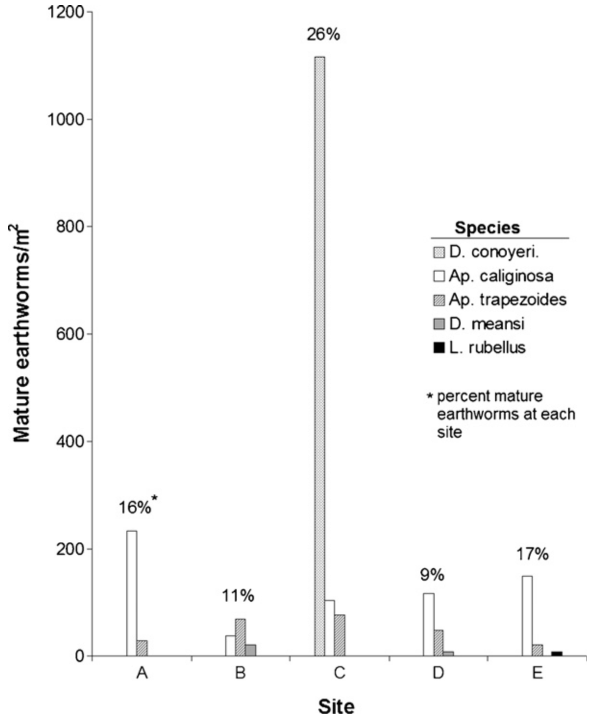

Fig. 5 – Number of earthworms of each species collected at each site with percent mature earthworms found at each site noted atop each bar.

exponentially with distance from the trench. Moreover, the relationships were strongest (i.e., highest r^2) when using only data from the 0.5–3 m distance from the trench. Additionally, sample points adjacent to the trench (0–0.5 m) weakened the relationships because values measured for this position were often similar or lower than for the 0.5–1.0 m position (Fig. 2).

A total of five earthworm species were identified at the five sites: *Aporrectodea caliginosa* Savigny, *Aporrectodea trapezoides* Dugès, *Diplocardia conoyeri* Murchie, *Diplocardia meansi* Gates, and *Lumbricus rubellus* Hoffmeister (Fig. 5). Diplocardia spp. are native to North America, while the other species are of European origin. *D. conoyeri* has not been previously reported in Arkansas and their identification is tentative since the specimens were shorter than typically described (Callaham, personal communication). Nevertheless, non-native species dominated at all sites except site C. Furthermore, *D. conoyeri* were observed only at this site and only in the two atypical transects, where they comprised the majority of the adult earthworms present (Fig. 5). Additionally, the average number of earthworms m^{-2} was 4–5 times higher in transects C2 (207 m^{-2}) and C3 (244 m^{-2}) than in the other transects (mean 48, range of 21–83 m^{-2}) (Fig. 2).

4. Discussion

In 13 of the 15 transects, earthworm numbers and biomass were significantly greater in the vicinity of the soil-treatment-system trenches with the effect still noticeable at a distance of

3 m from the trench (Fig. 2). Thus, the addition of household effluents must have had a positive effect on earthworm population. Previous research in agricultural fields has shown that earthworm numbers and biomass are greater in drained than in undrained fields (Carter et al., 1982) and that populations and biomass are greater directly above subsurface drains than between drains (Nuutinen et al., 2001; Urbánek and Doležal, 1992). Nuutinen et al. (2001) speculated that the higher populations above subdrains were due to better soil aeration. On the other hand, Urbánek and Doležal (1992) attributed these higher populations to a greater abundance of soil organic matter in the trench backfill than in the surrounding soil. In our study, however, since the drain lines were discharging organic substrate and nutrient-laden effluent, aeration was most likely poorer near the trenches than at the more distant sampling points. Thus, better aeration of the soil near the trenches could not account for observed population increases.

In general, additions of animal wastes to soils, including those applied as slurries, have been shown to increase earthworm populations (Curry, 2004). For instance, Curry (1976) showed that slurried animal wastes increased earthworm populations up to 53%, and Satchell (1955) noted that earthworms were 3–4 times more numerous in manured than in non-manured grassland plots. In our study, it is likely that the household wastes discharged in the trenches increased the food supply for earthworms and increased earthworm populations. This increase in nutrients and food supply was evident based on lush growth of vegetation in the vicinity of the trenches prior to earthworm sampling.

The fact the populations were not as large 0–0.5 m from the trenches as they were 0.5–1.0 m away (Figs. 2 and 3) suggests that the positive effect of the effluent on the earthworms may have diminished directly above the drain lines. Previous research has demonstrated that high levels of ammonia and organic salts in liquid animal wastes can be toxic to earthworms (Curry, 2004), and it is possible that unfavorable chemical conditions occurred in the immediate vicinity of the drains. Any negative effect of effluent on earthworms in the soil is likely minimal. Jones et al. (1993) observed a survival rate of 81% for *L. rubellus* and 95% for *L. terrestris* with a loss in dry weight of less than 4% in soil columns dosed with septic tank effluent over a 95-d period. Furthermore, Bouma et al. (1975) observed fresh earthworm excretions and large, open, vertical channels in the infiltrative surface of a soil-treatment trench bottom.

The lack of a relationship between earthworm populations and distance from the trenches in transects C2 and C3 may be explained by the distribution of earthworm species at the five sites. The reason *D. conoyeri* were only found in these two transects is unknown, but their presence in high numbers and as the dominant species probably contributed to the atypical relationship between distance and earthworm populations observed in these transects.

Nearly all of the earthworms identified were endogeic species, except *L. rubellus*, which is epigeic. No anecic (i.e., deep burrowing) species were observed, which would be of greatest concern in filter fields. Consequently, the potential for reduced renovation due to earthworm activity at the sites evaluated is low. However, this may not be true for other areas. Although the anecic earthworm *L. terrestris* is common in North America (Reynolds, 1995), Northwest Arkansas is on the edge of its known distribution, which may explain why none were observed. If anecic earthworms were present and their populations were greater near the trenches, their burrows could have penetrated the infiltrative surface, allowing for bypass flow and reduced renovation The increased populations of endogeic earthworms near the trenches we observed may result in a greater lateral spread of effluent and hence a greater volume of soil available for renovation.

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